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Bladder Neck Moves in a Correlated Manner During Gluteal Muscle and Pelvic Floor Muscle Contractions: Gluteal Muscle Contraction as Easily Confirmable Pelvic Floor Muscle Training

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Urinary incontinence is defined as the complaint of involuntary leakage of urine, of which incidence is increased with aging. It is well known that gluteal muscle (GM) and pelvic floor muscle (PFM) contract simultaneously; the former serves as extension or external rotation of the hip joint, while the latter does as the supportive function of abdominal and pelvic organs. We have shown that bladder neck movement analyzed by magnetic resonance imaging (MRI) was useful for understanding the beneficial effects of pelvic floor muscle training (PFM-training) on the prevention of urinary incontinence. In the current study, we hypothesize that (i) bladder neck movement accompanied by the GM contraction can be a landmark to evaluate the beneficial effect of PFM-training on urinary incontinence and (ii) hopefully, the GM contraction that can be identified easily from the body surface might be substituted for the PFM contraction. For this purpose, using cine MRI, the difference in bladder neck movement was compared between the GM and PFM contractions. Twenty-four women including 3 nulliparous and 21 primiparous women with the mean age of 29.5 years were included. Using a mid-sagittal section of cine MRI, the difference in height or position (anteroposterior position) of bladder neck was analyzed among the groups at rest, during GM and PFM contractions. In this study, the maximum change of bladder neck movement induced by involuntary GM was almost the same as that induced by PFM contraction. Likewise, during the first 10 seconds of the scanning periods, the longitudinal change of bladder neck movement did not show any significant difference between the GM and PFM contractions. These findings place an emphasis on the potential benefit of the GM contraction during PFM-training against urinary incontinence in the routine clinical setting. Our approach of applying the tactile GM contraction to the PFM-training program can surely pave the way for establishing the practical method to overcome the uncomfortable urinary incontinence that is more likely to affect the routine quality of life.

Key words: gluteal muscle contraction, pelvic floor muscle contraction, bladder neck, pelvic floor muscle training, stress urinary incontinence, magnetic resonance imaging

INTRODUCTION

Urinary incontinence is defined as the complaint of involuntary leakage of urine, and is classified into 3 groups such as stress, urgent, and mixed types of urinary incontinence [1]. Especially, stress type of urinary incontinence (SUI) is common in female between the ages of 15 and 64 years with its morbidity ranging from 10% to 30%, which also exert a negative impact on the quality of life (QoL) of affected women [2-4]. Although the continence control system is complex and not fully understood, it consists of a pelvic floor (PF) supportive structure including the striated levator ani muscle (LA), connective tissues interspersed with smooth muscle and sphincter unit with multilayered urethra [5, 6]. The

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weakening of the pelvic floor muscles (PFMs) and their supportive structures due to aging or childbirth, and other changes involving anatomical relationship between the urinary bladder neck and intrinsic sphincter of the urethra have been implicated as the etiology of SUI [2, 4, 7, 8]. Besides, neural controls of these structures are also complicated and remain controversial.

Due to the negative impact of SUI on QoL, the management of SUI appears to be essential for having and keeping better QoL. As a lesser invasive option, the conservative management is often provided prior to surgical treatment because of SUI not progressing in a short period of time. The pelvic floor muscle training (PFM-training) has been considered as effective and preventive against the progress of urinary incontinence, with which a recommendation of Grade B has been provided by the International Continence Society. Likewise, as a first-line of therapy the PFM-training has a recommendation of Grade A to all women irrespective of stress, urge, or mixed type of urinary incontinence, [4,9-11]. Although the mechanism underlying the effect of PFM-training on the prevention of SUI has been postulated using static and functional magnetic resonance imaging (MRI)[12-15], the rationale of the PFM-training to manage the SUI still remains to be elucidated.

Using cine MRI, we have found the effect of PFM-training on urinary incontinence is well correlated with morphological changes of bladder neck such as forward movement by increased tension of the LA and upward movement by improved contractile strength of the PFM [16]. An ideal methodology for the PFM-training is to promote the correct PFM contraction and to prevent the undesirable antagonistic muscle contractions (abdominal and gluteal muscles [GM])[11,17], while it is not easy to separately identify and contract the target muscles of the PFM due to their deep location in the pelvis, even in the healthy women.

In the present study, using cine MRI, the different findings between the effects of GM and PFM contractions relating the bladder neck movement were compared. The aim of this study is to examine whether the GM contraction, which can be visualized and identified from the surface of the body, can build a promising rationale to improve the conventional approach of the PFM-training.

MATERIALS AND METHODS

1) *Participants*

Twenty-four females (3 nulliparous, and 21 primiparous within 6 months of normal vaginal delivery) were included in the study. The mean age was 29.5 ± 4.5 years (21 to 38 years). The mean body mass index (BMI) was 20.3 ± 2.0 kg/m^2 (17.2 to 24.2 kg/m^2) (Table 1). Before inclusion, all participants had no experience with PFMT. The present study was approved by the Ethical Review Board of the Institution (Approval number 81). The written form of informed consent was obtained from each study participant.

2) *Qualitative analysis of urinary incontinence*

The International Consultation of Incontinence Questionnaire-Short Form (ICIQ-SF) was obtained on the day of the survey [10,18]. This survey is comprised of 4 questionnaires about the frequency of UI, degree of UI, hindrance to daily living resulting from UI, and the type of UI. The first 3

Table 1. Characteristics of the study participants (n = 24)

Group	n	Age, years			BMI, kg/m^2		
		Mean		SD	Mean		SD
All	24	29.5	±	4.5	20.3	±	2.0
Nulliparous	3	23.0	±	0.0	19.0	±	2.1
Primiparous	21	30.4	±	4.0	20.5	±	2.0

BMI, body mass index; SD, standard deviation questionnaries are scored on a scale from 0 to 7. The total score ranges from 0 to 21.

3) Morphological evaluation of PF support structures by MRI and explanation of GM and PFM contractions

Instruction of how to construct the target muscle consisted of the following steps;

a) to contract the gluteus maximus muscle (GMM) towards the midline in the way that the buttocks touch, for the purpose of increasing the strength of the contraction which may allow the GMM contraction to be recognized subjectively and objectively.

b) to bring the GMM together towards the midline allowing for lateral rotation in addition to the extension of the hip joint. Since the GMM arises from the posterior/medial surface of the hip bone and sacrum medially and inserts to the gluteal tuberosity of the femur laterally, lateral rotator muscles of the hip joint are also activated. GMM contraction was confirmed through touch by each participant and the researcher.

c) to contract PFM was described to the participants as a motion when quitting the voiding with illustrations of the PFM.

4) MRI scans condition to evaluate the morphological change of bladder neck

According to the previous report [19], the bladder scan was performed using a high-speed 1.5-T MAGNETOM Symphony scanner (SIEMENS, Munich, Germany). Scanning conditions were as follows: slice thickness/slice intervals were 5 mm/0.5 mm for cross-sectional images and 5 mm/1 mm for sagittal images; field of view was 220 mm for cross-sectional images and 240 mm for sagittal images; matrix size was 256×205 mm for cross-sectional images and 448×180 mm for sagittal images; and repetition time (TR)/echo time (TE) was 4580/111 for cross-sectional images and 3300/100 for sagittal images, where the number of excitations (NEX) was assumed to be 2. Then, a dynamic scan using gradient sequence true FISP (high-speed) cine MRI was done with the following conditions; the slice thickness/slice intervals were 5 mm/1 mm, with a field of view of 300 mm, matrix size of 256×210, TR/TE of 4.3/2.15, and NEX of 2. To evaluate the bladder neck movement, scanning was performed at 1 frame per second. To standardize the volume of urine in the bladder during the scan each participant was instructed to void one hour before the scan, and then to drink 300-500 ml of water, so that bladder volume would be greater than 150 ml.

5) Measurement of the mobility of the bladder neck by cine MRI

Anteroposterior and craniocaudal movement of the bladder neck was analyzed in the midsagittal section based on our previous paper [16]. To avoid the unconscious PFM contractions affecting the changes of bladder neck position caused by GMM contractions appears to be the most important. Briefly, the scanning methods were as follows; (1) a 5-s scan at rest, and (2) a 10-s scan of GMM contractions, followed by a 5-min break to allow time for instructions regarding PFM contractions. Scanning resumed with (3) a 5-s scan at rest, followed by (4) a 10-s scan of PFM contractions. Cine images were captured at 1 frame per second with a total of 30 frames per participant. The height of the bladder neck was defined as the length of the straight line from the bladder neck that is perpendicular to the intersection with the base line connecting the lower end of the sacrum and pubis. The anteroposterior (dorsoventral) position of the bladder neck was defined as the distance from the sacrum to the bladder neck in a line parallel to the base line. Data were saved in Digital Imaging and Communications in Medicine (DICOM U3) format and were assessed using AZEWIN medical image analysis software (AZE Technology, Inc., Tokyo, Japan).

6) Statistics analysis

In the bladder neck height/position, the relationship between GMM and PFM contractions was evaluated by univariate regression analysis using the average of maximum values for each participant. We also evaluated the sustainability of the 10-s contraction by the test of the uniformity of the distribution of measured values during GMM and PFM contractions. Stastical analysis was performed using the SPSS version 16.0 with p value of less than 0.05 being statistically significant.

Table 2. UI of the participants

Group	n	ICIQ-SF (0-21 point) Mean	±	SD	Min	Max
All	24	29.5	±	4.5		
Nulliparous	3	0.0	±	0.0		
Primiparous with urinary incontinence	7	4.3	±	2.4	2	8
Primiparous with no urinary incontinence	14	0.0	±	0.0		

Min : minimum

RESULTS

1) ICIQ-SF results

In the present study, 7 primiparous women were found to be aware of having UI according to the ICIQ-SF results. However, their symptoms were assumed to be mild because of their total scores ranging from 2 to 8. These seven participants were aware of having UI caused by increased abdominal pressure such as coughing, sneezing and running. No significant differences in all the examined items among nulliparous women, primiparous women without UI, and primiparous women with UI (Table 2). Based on this preliminary analysis, the results here obtained are the analysis from total of all 24 participants.

2) Effect of muscle contraction on the height of the bladder neck

The mean height of the bladder neck was 19.2 ± 4.8 mm at rest, 24.0 ± 5.4 mm during GMM contraction, and 24.2 ± 5.4 mm during PFM contraction. Maximum bladder neck height was significantly higher during GMM and PFM contractions than at rest ($p < 0.05$; Table 3). As shown in Fig. 1a, the effect of GMM contraction on the maximum bladder neck heights was significantly correlated with that of PFM contraction ($r = 0.946$; $p < 0.001$). As shown in Fig. 1b, no significant difference was found between GMM and PFM in the movement of bladder neck expressed as the mean height during the 10 seconds of muscle contraction ($p = 0.999$).

3) Effect of muscle contraction on the position of bladder neck

The antero-posterior position of the bladder neck was 93.6 ± 6.4 mm at rest, 95.8 ± 6.8 mm during GMM contraction, and 96.8 ± 6.4 mm during PFM contraction. Anterior movement of the bladder neck was found, though smaller in scale, during the GMM and PFM contractions. No significant difference in the bladder neck position was found among the groups at rest, during the GMM and PFM contractions (Table 4). On the other hand, as shown in Fig. 2a, the bladder neck position during the GMM contraction was almost the identical to that during the PFM contraction ($r = 0.967$, $p < 0.001$). As shown in Fig. 2b, the mean bladder neck position is slightly higher during PFM contraction than GMM contraction. However, during the 10 seconds of scanning periods, the longitudinal change of bladder neck position did not show any significant difference between GM and PFM contractions ($p = 0.999$; Fig. 2b).

Table 3. The height of the bladder neck

Condition	Mean ± SD (mm)	*p*
At rest	19.2 ± 4.8	0.003
Gluteus maximus muscle contraction (max)	24.0 ± 5.4	
At rest	19.6 ± 4.2	0.001
Pelvic floor muscle contraction (max)	24.2 ± 5.4	

Mann – Whitney U test

Table 4. The position of the bladder neck

Condition	Mean ± SD (mm)	*p*
At rest	93.6 ± 6.4	0.244
Gluteus maximus muscle contraction (max)	95.8 ± 6.8	
At rest	94.3 ± 5.9	0.07
Pelvic floor muscle contraction (max)	96.8 ± 6.4	

Mann – Whitney U test

DISCUSSION

The conservative approach seems to take priority over any surgical methods to treat and/or manage the urinary incontinence. The PFM-training program is the best conservative way to overcome the uncomfortable urinary incontinence [4, 9, 11, 17]; however, the major concern about this program is that it will take a longer time to get the subjective improvement of urinary incontinence. Besides, not only for the trainees but also for the instructors, the subjective parameters associated with proper contraction of the targeted PFMs might be hardly available [19-21]. Thus, if the targeted muscles are well organized and visualized by both the trainees and instructors during the training program, the approach will be accepted universally. Taking these backgrounds into consideration, we hypothesize that voluntary and tactile contraction of GM could replace the functional role of PFMs as the target parameters of the muscle training.

The pelvic floor is mainly composed of 4 muscle fibers such as levator ani (LA), external urethral sphincter (EUS), transverse perineal muscles and coccyges muscles, among which the former two muscles will serve as major functional "apparatus" to maintain the urinary continence against the abdominal pressure. In the present study, the bladder neck movement induced by GMM contraction was found to be almost the same as that induced by the PFMs contraction. Likewise, during the 10 seconds of muscle contractions, the longitudinal changes of bladder neck movement such as height and position showed the same pattern with no significant differ-

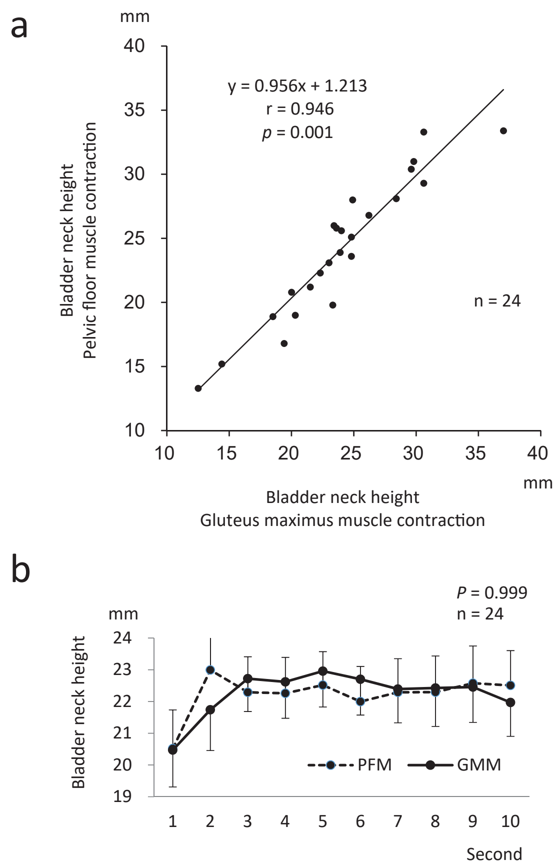

Fig. 1. Maximum bladder neck height during gluteus maximus muscle (GMM) and pelvic floor muscle (PFM) contractions. a. Correlation in maximum height of the bladder neck between GMM and PFM contractions. b. Distribution of bladder neck height during 10s of GMM and PFM contractions. n = 24, p = 0.999.

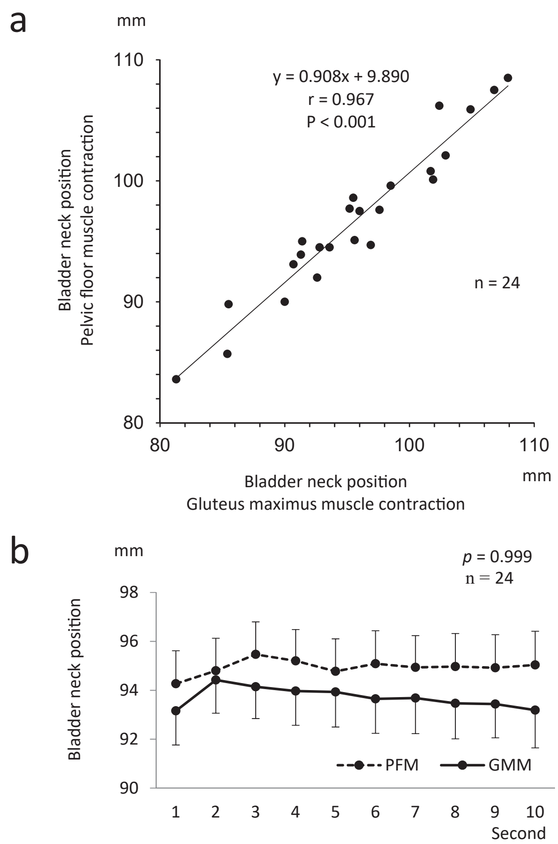

Fig. 2. Position (maximum distance from the sacrum) of the bladder neck during gluteus maximus muscle (GMM) and pelvic floor muscle (PFM) contractions. a. Correlation in position of the bladder neck between GMM and PFM contractions. b. Distribution of bladder neck position during 10s of GMM and PFM contractions. n = 24, p = 0.999.

ence between the GMM and PFMs contractions. In fact, needle EMG and MRI have shown that the majority of LA and GM fibers were simultaneously affected with 80% activated bilaterally during the voluntary contraction of PFMs [15]. It has been reported that 2 components of LA fibers showed different movements during the LA activation; namely, the puborectalis moves antero-posteriorly, whereas the iliococcygeus moves cranio-caudally [19]. This means that the PFMs contraction is associated with potentially different directions of the movement such as forward movement to close the urogenital hiatus and upward one to lift up the urethra and bladder. Since the essential part of PFM-training is related to the positional control of the deviated bladder neck, the voluntary GMM contraction causing the involuntary PFMs contraction is responsible for the positional change of bladder neck such as forward and upward movements. Previous reports indicate that abdominal muscles, GM, and PFM are activated simultaneously [22,23]. Simultaneous contractions of the PFM and GM have been observed with needle electromyography (EMG) of the striated urethral wall [24]. In addition, voluntary contraction of the PFM has been shown to induce simultaneous movement of the LA and GM in the same direction through the ischiorectal fossa [15]. These findings place an emphasis on the GMM having a good chance to be substituted for PFMs as an effective moderator of the PFM-training program. In turn, our results suggest that the tactile GMM contractions, which are subjectively easier to confirm than PFMs contractions, may serve as an effective "device" of the PFM-training.

The mechanism underlying the voluntary GMM contraction induces indirect and involuntary PFMs contraction remains to be elucidated. As shown in Fig. 3, the GMM and PFMs are innervated by the somatic motor neurons from the sacral and coccygeal plexuses [25]. The lateral sacral plexus is composed of the S1–S4 nerves and L4/L5 lumbosacral nerve root. The GMM is innervated by the inferior gluteal nerve, which branches off the posterior L5–S2 sacral plexus. On the other hand, the PFMs are innervated by the pudendal nerve originating from anterior S2–S4 sacral plexus as well as tributaries of the sacral plexus [25]. Thus, the GMM and PFMs innervations share a couple of same nerve fibers, providing the rationale of simultaneous contraction between GMM and PFMs.

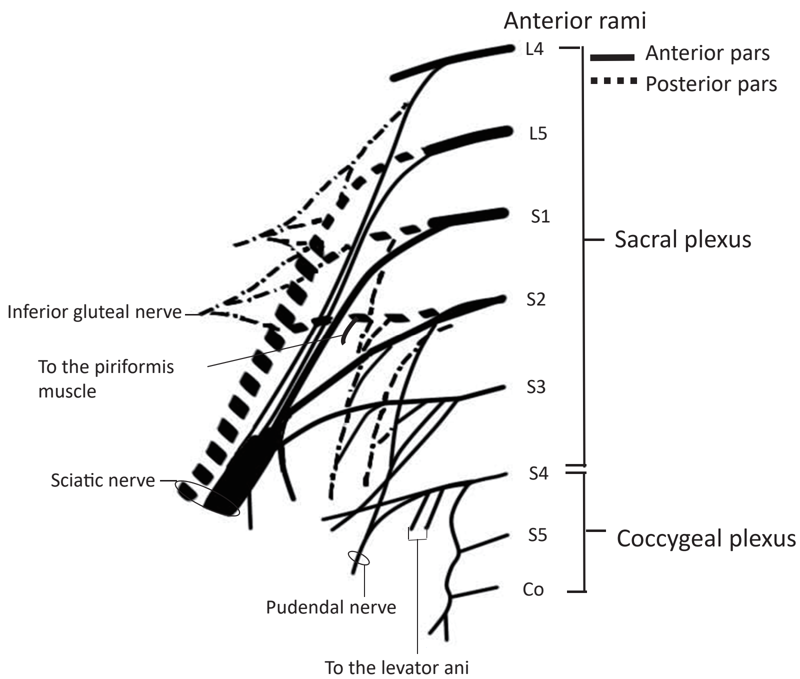

Fig. 3. The sacral and coccygeal plexuses (modified from [25]). Solid line: anterior (ventral) parts, Dotted line: posterior (dorsal) parts.

It has been postulated that the essential part of PFM-training might be positional correction of the deviated bladder neck and functional improvement of external urethral sphincter (EUS) [24, 26-28]. Therefore, as a 2nd step, the clinical resolution of the issues involving urinary incontinence depends on how much we can understand the functionally organized pelvic floor structures, namely the correlation of the GM contraction with activation of EUS. As shown in Fig. 3, the nerve fibers originated from S2 innervating LA surely share and communicate those fibers of pudendal nerve. It might be plausible that the activation of S2 fibers could induce not only LA contraction and piriformis but also EUS through simultaneous activation of pudendal nerve.

Although we have discussed the impact of coordination of the GMM and EUS on the prevention of urinary incontinence, the key issue of getting close to the EUS activation is the pudendal nerve stimulation. Keeping in mind the innervation of GMM and piriformis includes the S2 nerve fibers which share the pudendal nerve [29], the voluntary GMM contraction with lateral rotation of the hip to bring the bilateral GMM towards the midline direction may cause greater nerve stimulation than simple voluntary contraction of the GMM alone, and thus induce stronger activation of the pudendal nerve and stronger contraction of the EUS as a result.

In summary, we have developed more practical way to obtain an effective machinery on the prevention of urinary incontinence, where the emphasis should be placed on the pudendal nerve activation that is surely associated with not only the GM contraction but also EUS activation. The most beneficial part of the GM contraction in the PFM-training program is to be visualized and easily identified from the surface of the body. The benefit of treating program using GMM was emphasized in this paper.

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DISCLOSURE STATEMENT

All authors have nothing to disclose related to the content of this study.

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